Is There a 'Conservation of Information Law' for the Universe?

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Abstract

What are the implications if the total 'information' in the universe is conserved? Black holes might be 'logic gates' recomputing the 'lost information' from incoming 'signals' from outside their event horizons into outgoing 'signals' representing evaporative or radiative decay 'products' of the reconfiguration process of the black hole quantum logic 'gate'. Apparent local imbalances in the information flow can be corrected by including the effects of the coupling of the vacuum 'reservoir' of information as part of the total information involved in any evolutionary process. In this way perhaps the 'vacuum' computes the future of the observable universe.

1 Introduction

Let us begin with the assumption that there may exist a Conservation of Total Information 'law' for the entire universe. The motivation for this is based in the idea of conservation of total mass-energy for the universe regardless of the forms matter takes during the reconfiguration processes of matter within the framework of an expanding vacuum filled with growing quantum networks [1].

If all current visible structures floating on the sea of the vacuum constitute a very small percent of the total 'information' in the entire universe and the 'expansion' of 'space' combined with local gravitationally driven aggregation of mass into 'information' sources and sinks (such as stars and planets for instance) provide a means for 'computing' new configurations of matter (biological systems for instance), then perhaps the remainder of the 'invisible information' is in the vacuum 'reservoir'. All unstable 'visible' physical systems such as atoms and molecules represent the building blocks for complex hierarchical systems.

If one were to take this view then the apparent information 'loss' by 'evaporation' in black holes could be recast as the 'computation' of new forms of information (Hawking radiation) by the black hole 'logic gate' in a quantum computer space (vacuum). The signals emanating from the black hole carry information content about the logical operations performed on the incoming mass 'signals' contributing to the process of black hole formation. The black hole recomputed its unstable state (coupled to the vacuum) into a more stable one in which outgoing signals are 'emitted'. The analogy is similar to the processing of incoming photons by the electrons around an atom into emission spectra.

Since new structures clearly emerge from previous 'unstable' configurations of matter in the universe, new information also emerges as a function of the entanglement of new combinations of quantum systems into a single system with collective behaviors that are more than a linear sum (actually a 'direct product') of the component systems by themselves. New information can be created locally then but overall information may be conserved for the universe as a whole due to the conversion of information from the expanding vacuum reservoir into novel configuration information defining the islands of matter throughout the universe.

2 Black Hole Quantum Logic 'Gates'?

Let us begin by looking at black holes as quantum computer logic gates in which incoming matter (information) signals are recomputed into outgoing decay product 'signals'. The 'difference' in the form and content of the 'information' between incoming and outgoing signals is the result of the coupling of the black hole to the expanding space (vacuum) information reservoir. In this sense the composite system of space and matter forms at least a network of local quantum computers in the neighborhood of black holes.

The universe may then be a form of 'quantum computer' [2] *network* of black hole logic gates or other complex matter 'computers' whose power to recompute the evolutionary progression of global states of the expanding universe is due their use of the vacuum reservoir of information created by the gravitational interaction of matter bound to the sea of vacuum energy upon which they are small components.

M. M. Cirkovic's idea ([3]) that there may be no primordial black holes (certainly believable in light of the absence of appropriate gamma ray spectra) combined with the possibility that any black holes formed during the evolution of the universe might not trap or evaporate enough 'information' at a rate significant enough to create an imbalance in the total information of the universe might be seen as a 'hint' that total information content in the universe may to first order be conserved. Black holes are generally regarded as information 'sinks' but they are still within the universe. While the information is usually thought of as being 'lost' inside a BH, if we take the view that the BH is a sort of 'memory' or logic gate connected with the rest of the universe through its coupling to the vacuum (expanding space) then the expanding universe is engaged in a 'race' between the 'creation', 'processing', 'transformation' and 'destruction' of 'information' encoded in complex physical system 'islands' in the vacuum info-space. The rate of expansion (possibly accelerating according to recent supernovae observations) can be used to test whether a conservation of information law is valid.

The information processing time (lifetime?) of a black hole seems to be dependent on the information (e.g. consumed 'signals' plus remnant mass of its stellar progenitor) that it holds. Even if this information is an entangled 'collective excitation' mess, it can decohere (by a vacuum-BH interaction that triggers the 'output' of decay products?) via the vacuum induced evaporation of the BH at a critical transition 'mass'. The key to accounting for all the information is to remember that the black hole exists only because there is an environment (the vacuum) that defines it.

Black holes represent one of the fundamental testing grounds for a conservation of information law for the entire universe. Any unstable system presents the opportunity to test conservation of information. Black holes and the interest in irreversible loss of information seems to have caught the imagination of cosmologists and those interested in quantum processes in which information is encoded in the form of 'observable' properties of 'physical' systems. There is a possibility that the 'entropy' issues can be clarified when considering the 'remainder' of information shifted into the vacuum 'information reservoir' after processing of the 'lost' signals (e.g. signal trapping and mass accretion resulting in creation of at least one 'signal' in the form of the 'inflation of event horizon', etc.) into outgoing signals during the evaporation or decay process. Gravity is a sort of adaptive 'wiring' between BHs and matter outside the event horizon.

Black holes viewed as computational logic gates that recompute gravitationally wired signals into new forms of information provide a logical source for Hawking radiation and other possible 'evaporation' signals. This perspective might illuminate the features of a general information conservation law that can be used to establish how complex systems can arise as the result of the computational effects of expanding vacuum upon the matter within it.

2.1 Info-flow through BH Gates

The state of the entire universe, $|U\rangle$, is the direct product its entangled component sub-states including the vacuum $|V_U\rangle$, the physical (observable) 'matter' sub-systems $|S_U\rangle$ (such as particles, nuclei, atoms, molecules and gravitational aggregations of these in planets, stars, galaxies and life-forms), 'signals' $|\lambda_U\rangle$(e.g. photons)and the expansion 'boundary condition' or 'surface area' of the 'event horizon' of the expanding vacuum energy density characterized by the expansion front bubble surface area, $|A_U\rangle$:

$$|U\rangle = |V_U\rangle \bigotimes |S_U\rangle \bigotimes |\lambda_U\rangle \bigotimes |A_U\rangle \tag{1}$$

Which becomes:

$$|U\rangle = |V_U\rangle \bigotimes \left[\bigotimes_{i=1}^{\infty} |S_i\rangle\right] \bigotimes \left[\bigotimes_{j=1}^{\infty} |\lambda_j\rangle\right] \bigotimes |A_U\rangle \tag{2}$$

Where causal networks can be formed by destabilized physical subsystems and the signals between them in a general environment of an expanding vacuum 'information' reservoir bounded by a computational enclosure of the expansion front metricized by the Hubble flow and large scale dynamics of galaxies. We note here that the 'vacuum' is not empty, but to the contrary, contains most of the information in the universe. The observable matter we consider to be the sources of information about the large scale structure of the universe are relic computational perturbations from the anisotropic phonon-like collective excitation decay modes of the inflationary epoch. The Planck scale relics were 'computed' into the particles we are built by the conversion of the localized energy of the Planck epoch universe into 'decay products' like matter and the vacuum.

If we look at information flow through a single black hole logic gate, $|BH\rangle$, we see that an incoming signal, $|\lambda_{IN}\rangle$, 'lost' by entering a BH gate is computed into to new signals such as the quantized increase in the area of the event horizon, and a quantized increase in the total mass of the BH. If the BH mass is below the critical excited state at which quantum evaporation processes result in signal emissions, then the BH act like a long term RAM storage device or memory for the incoming signals delivered by the gravitational 'wiring' of the vacuum to external sub-systems of the universe. At this point total information is still conserved and the 'lost' information embedded in the BH has been computed into observable changes in the collective excitation states such as total BH mass and event area.

The state of the BH subsystem, $|S_{BH}\rangle$, encompassing the space in which incoming signals make a transition from 'classical' separation (i.e. superposition) to quantum coupling (detection, absorption, or entanglement) before gravitational detection of a signal, ignoring for the moment the expansion area boundary conditions, $|A_U\rangle$, for the rest of the universe, is a 'classical' quantum system:

$$|S_{BH}\rangle_C = |BH_0\rangle + |\lambda_{IN}\rangle \tag{3}$$

Upon detection of the signal by gravitational trapping of the 'quantum' state of the BH system, $|S_{BH}\rangle_Q$, and the 'excited' state, $|BH^*\rangle$, of the BH information processing system is a composite system of the entangled signal, $|\lambda_{IN}\rangle$, with the BH 'mass' inside its now expanded event horizon. The increase in the event horizon area is $|\delta A_{BH}\rangle$, and therefore information content of the BH is characterized by $|BH^*\rangle$:

$$|S_{BH}\rangle_Q = |M_{BH}\rangle \bigotimes |\lambda_{IN}\rangle = |M_{BH}\rangle \bigotimes |\delta A_{BH}\rangle = |BH^*\rangle \tag{4}$$

The decay of this state occurs only if it is the critical evaporation threshold state, $|S_{BH}\rangle_{Critical}$. The system can gravitationally detect a 'less than infinite' number of signals in a series of hierarchical excited states corresponding to the increased mass and computational (event horizon) surface area before it reaches this state in which the gate converts the event horizon and accretion mass information as Hawking evaporation signals. If the BH system is at a point where the emission of signals by 'evaporation' occurs then the coupling of the vacuum to the remnant links the differences in the form and content of the pre-BH processed signals to the emitted post computation signals.

Since all forms of information during the process of 'loss' and delayed 'evaporation' in black holes (including any entropy terms that are in fact communicated to the vacuum information reservoir) can be accounted for, we see that black holes obey conservation of total information when all system components and environment involved in the reconfiguration of information from input to output are taken into account.

This limiting case of conservation of information for a black hole illustrates that a conservation of information law for the entire universe may provide a convenient tool for understanding fundamental processes, the evolution of complex systems and cosmological effects in local 'matter' islands.

Remark 1 *Note that this process pertains also to non-BH physical systems that detect and process information such as Feynman Cocks (FCs), Collective Excitation Networks (CENs) and Sequential Excitation Networks (SENs) [4], [5], [6].*

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[6] **"Feynman Clocks, Causal Networks, and Hierarchical Arrows of Time in Complex Systems From the Big Bang to the Brain"** An invited talk and paper given by *Scott Hitchcock* at the 'XXIII International Workshop on the Fundamental Problems of High Energy Physics and Field Theory' at the Institute for High Energy Physics (IHEP), Protvino, Russia, June 21-23, 2000. To be published in the Proceedings of the Workshop and as NSCL as preprint (MSUCL -1172). It is also at the Los Alamos National Labs, LANL e-Print Archives report number quant-ph/00100014. Available at http://www.nscl.msu.edu/news/nscl_library/nscl_preprint/MSUCL1172.pdf